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Original article

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Abstract

Background

To date, there are limited Australian data on characteristics of people diagnosed with COVID-19 and on how these characteristics relate to outcomes. The ATHENA COVID-19 Study was established to describe health outcomes and investigate predictors of outcomes for all people diagnosed with COVID-19 in Queensland by linking COVID-19 notification, hospital, general practice and death registry data. This paper reports on the establishment and first findings for the ATHENA COVID-19 Study.

Methods

Part 1 of the ATHENA COVID-19 Study used Notifiable Conditions System data from 1 January 2020 to 31 December 2020, linked to: Emergency Department Collection data for the same period; Queensland Health Admitted Patient Data Collections (from 1 January 2010 to 30 January 2021); and Deaths Registrations data (from 1 January 2020 to 17 January 2021).

Results

To 31 December 2020, a total of 1,254 people had been diagnosed with SARS-CoV-2 infection in Queensland: half were female (49.8%); two-thirds (67.7%) were aged 20–59 years; and there was an over-representation of people living in less-disadvantaged areas. More than half of people diagnosed (57.6%) presented to an emergency department (ED); 21.2% were admitted to hospital as an inpatient (median length of stay 11 days); 1.4% were admitted to an intensive care unit (82.4% of these required ventilation); and there were six deaths. Analysis of factors associated with these outcomes was limited due to small case numbers: people living in less-disadvantaged areas had a lower risk of being admitted to hospital (test for trend, $p < 0.001$), while those living in more remote areas were less likely than people living in major cities to present to an ED (test for trend: p=0.007), which may reflect differential health care access rather than health outcomes *per se*. Increasing age (test for trend, $p < 0.001$) and being a current/recent smoker (age-sex-adjusted relative risk: 1.61; 95% confidence interval: 1.00, 2.61) were associated with a higher risk of being admitted to hospital.

Conclusion

Despite uncertainty in our estimates due to small numbers, our findings are consistent with what is known about COVID-19. Our findings reinforce the value of linking multiple data sources to enhance reporting of outcomes for people diagnosed with COVID-19 and provide a platform for longer term follow-up.

Keywords: COVID-19, epidemiology, outcomes, predictors, record linkage, surveillance, morbidity

Background

The novel coronavirus disease, named COVID-19 on 11 February 2020, is caused by the SARS-CoV-2 virus. It was first reported to the WHO Country Office in China on 31 December 2019. The outbreak was declared a Public Health Emergency of International Concern on 30 January 2020. As of 29 June 2021, there were over 181 million confirmed cases worldwide, with 2.9 million deaths.[1] Australia, partly due to successful contact tracing and isolation protocols, at the same time point had only 30,528 confirmed cases and 910 deaths, and in Queensland 1,686 confirmed cases and seven deaths.[2]

International data on outcomes among people who test positive for SARS-CoV-2, and on predictors of outcomes, have been reported throughout the pandemic.[3] However, outcomes are likely to vary with context, including population profile, extensiveness of surveillance and testing and health system characteristics. Furthermore, there has been much less data available on characteristics and outcomes for people diagnosed with COVID-19 in Australia. One study of 204 patients admitted to intensive care units in Australia between 27 February and 30 June 2020 found that 69% were men and 64% had comorbidities (mostly obesity, diabetes and chronic cardiac disease).[4] People with chronic cardiac disease, compared to those without, were 3.4 times more likely to die in an intensive care unit (ICU). Another more recent study focussed on hospitalisation rates in cases of COVID-19 diagnosed in New South Wales between 1 January and 31 May 2020. However, with the exception of age and gender, no other health characteristics were reported or linked to outcomes.[5]

It is essential that Australian- and state-specific surveillance systems monitor health outcomes and health service use as the pandemic progresses. This paper describes the establishment and first findings from the Australians Together Health Initiative (ATHENA) COVID-19 Study, which was set up to enable ongoing investigation of health outcomes including service use, and predictors of outcomes, for all people diagnosed with COVID-19 in Queensland. It does so by linking COVID-19 notification, hospital, general practice and death registry data.

The ATHENA COVID-19 Study has two parts (see Methods section for detail). Part 1 links Queensland COVID-19 notification, hospital and death registry data and does not require informed consent (access was granted under Section 282 of the *Public Health Act 2005*). Part 2 links Queensland COVID-19 notification, hospital and death registry data, as well as patients' healthcare information held within general practices, and requires patient consent.

The aim of this paper was to report on the establishment and results for Part 1 of the ATHENA COVID-19 Study. We describe hospital-based outcomes and deaths among all people diagnosed with COVID-19 in Queensland, and estimate the strength of association between these outcomes and sociodemographic and pre-existing health characteristics based on routinely-collected data.

Methods

ATHENA is a Queensland-Health-funded program involving the integration of primary, secondary and other healthcare data sets, using informed consent across Queensland. A proof-of-concept study was completed in June 2019 involving over 500 patients routinely attending two general practices. The principal purpose of this proof-of-concept study was twofold. Firstly, to assess the proportion of patients consenting to have their primary healthcare data extracted from their general practice into Queensland Health and linked to other data sets for ethically-approved research. Secondly, to gain permission to recontact them in future to discuss clinical trial participation. Consent was given by 80% of patients to both have their data exported and linked, and to be recontacted for trial participation. The successfully-linked healthcare data were tested and found to be highly informative for clinical trial design and feasibility testing,

while also providing rapid access to large numbers of appropriate patients for real-world clinical trials. The ATHENA COVID-19 Study was opportunistically set up at the start of the pandemic, using the same methods to create a cohort of all people diagnosed with COVID-19 in Queensland with linked primary, secondary and registry data. These patients would be followed from recorded symptom onset date, to measure health service use and outcomes and to investigate predictors of these outcomes, as well as to provide an ongoing resource for future clinical trial recruitment.

Data

Part 1 of the ATHENA COVID-19 Study used routinely-collected data from the Notifiable Conditions System (NoCS) for all people who tested positive for the SARS-CoV-2 virus in Queensland, linked to data from the Emergency Department Collection (EDC), the Queensland Health Admitted Patient Data Collection (QHAPDC) and Deaths Registrations. The NoCS data (1 January – 31 December 2020) contained symptom onset date, sociodemographic characteristics and health outcomes. The EDC data (1 January – 31 December 2020) included emergency department (ED) arrival and departure dates and principal diagnosis. The QHAPDC data (1 January 2010 – 30 January 2021) contained admissions data from all public hospitals in Queensland, including admission and separation dates, and diagnosis codes. In Queensland, people diagnosed with COVID-19 have only been admitted to public hospitals. Death Registrations data were available from 1 January 2020 to 17 January 2021. Data were linked probabilistically, using name, date of birth and address by the Statistical Services Branch within Queensland Health, applying established protocols.[6]

Sample

The sample for this study included all people in Queensland who tested positive to the SARS-CoV-2 virus resulting in COVID-19 (n = 1,254), identified using NoCS data, from 1 January 2020 to 31 December 2020 (referred to as the Queensland COVID-19 cohort).

Hospital-based outcomes and death

The primary outcomes of interest were: presentation to an ED; inpatient admission to a public hospital (which excluded virtual ward at home); admission to ICU; use of continuous ventilator support; and death. Secondary outcomes were time spent: in hospital; in ICU and on ventilation; as well as time between onset date and first hospital admission, and between ICU admission and death.

Presentation to an ED was ascertained from the EDC data. Admission to ICU (standard ward codes 'ICU4', 'ICU5' or 'ICU6') and continuous ventilator support were ascertained from the linked QHAPDC data. We included ED presentations and hospital admissions that occurred on or up to 6 weeks after symptom onset date, or where admission included date of onset.

Sociodemographic and health characteristics

Sociodemographic characteristics included age (in broad age groups); sex; remoteness (measured with Accessibility and Remoteness Index of Australia [ARIA+]);[i] socioeconomic status (measured using Socio-Economic Indexes for Areas, Index of Relative Socio-Economic Disadvantage, [SEIFA IRSD]);[ii] smoking status; and health conditions, categorised as shown in Table 1.

Smoking status was obtained using information from all available QHAPDC records (i.e. prior to and after onset date, noting that collection of

i ARIA+ is a geographical measure of service accessibility based on road distances to service centres (based on population size), which groups areas into: major cities; inner regional; outer regional; remote; and very remote areas.[7]

ii SEIFA IRSD is an area-based measure of socioeconomic status, based on average characteristics of the people living within areas containing around 10,000 people.[8]

smoking status began on 1 July 2015 and was not recorded for virtual ward home admissions). People were categorised as a non-smoker if all QHAPDC records indicated that they were not a current smoker, or as a current smoker or recent smoker if at least one of their QHAPDC records indicated that they were a current smoker, or otherwise as missing (i.e. virtual QHAPDC records).

Comorbid conditions were identified using QHAPDC records in the ten years prior to onset date, and measured with International Statistical Classification of Disease and Related Health Problems Version 10 (ICD-10-AM) codes. We also used QHAPDC data to measure the Elixhauser comorbidity index,[9] a weighted algorithm based on 30 chronic health conditions identified using diagnosis codes, to categorise members of the cohort as having 0, 1, or 2+ conditions, or 'no hospital record prior to infection'. Separate categories were chosen to represent 'no hospital record prior to infection' and '0 comorbidities' because an absence of hospital record does not necessarily equate to an absence of patient comorbidity. Patients may have a history of medical disease yet may never have had contact with Queensland Health, the state's public health system, either because: the disease was never severe enough to require hospital admission; the patient may have been admitted to a public hospital outside Queensland; the patient may have been managed in the private system; or because the patient may have been managed in primary care.

Analysis

First we described the number and proportions of the cohort with each of the primary outcomes, as well as the median number of days (with interquartile range, IQR) in hospital and on continuous ventilator support. At the time of analysis, days spent in ICU were not available. We also cross-checked outcomes reported on the NoCS with outcomes derived from the linked data, by comparing primary outcomes recorded in the hospital and death data with those reported using NoCS data. Third, we quantified the association between sociodemographic and health characteristics and two outcomes: presentation to an ED and inpatient admission to hospital. In this part of the analysis, although a person may have more than one presentation to an ED or admission to hospital (event), the outcome was defined as ever compared to never had the outcome. We excluded ED presentations and hospital admissions where the first day of admission was more than 14 days after symptom onset to increase specificity of the estimates. We also excluded non-Queensland residents (n = 61, defined as having a principal address outside Queensland) to maximise the proportion captured with hospital admissions prior to infection. To assess associations between comorbid health conditions and ED and inpatient hospital admissions, we compared those with a given health condition to those without the condition with linked hospital records; those without linked hospital records prior to their onset date were included as a separate category. Associations were quantified with relative risks (RR) and 95% confidence intervals (95% CI), estimated using Poisson regression, with adjustment for age, sex and region of residence. Where appropriate, we also performed tests for linear trend by including ordered categories as continuous terms in models.

Two sets of sensitivity analyses were conducted. In the first, we re-estimated associations between comorbidities and hospital-based outcomes measuring comorbidities using all available QHAPDC data, i.e. additionally including admissions occurring after symptom onset date, to examine whether associations were similar when including diagnoses at the time of COVID-19-related admissions. In the second, we assumed that those without a hospital admission prior to their onset date did not have any of the measured comorbidities (previously included as a separate category), including any of the comorbidities measured with the Elixhauser index.

Where possible, we report results stratified by sex and broad age group. Missing data were included as a separate category. All analyses were conducted using Stata version 16.0.

Table 1: Characteristics of the Queensland COVID-19 cohort,[a] 1 January – 31 December 2020

		Male n (%)	Female n (%)	Total n (%)
Total		**630 (50.2)**	**624 (49.8)**	**1,254**
Age group (years)	0–19	38 (6.0)	34 (5.4)	72 (5.7)
	20–39	214 (34.0)	271 (43.4)	485 (38.7)
	40–59	200 (31.7)	164 (26.3)	364 (29.0)
	60–74	138 (21.9)	132 (21.2)	270 (21.5)
	75+	40 (6.3)	23 (3.7)	63 (5.0)
ARIA+[b]	Major cities	483 (76.7)	490 (78.5)	973 (77.6)
	Inner regional	67 (10.6)	66 (10.6)	133 (10.6)
	Outer regional / remote / very remote	46 (7.3)	40 (6.4)	86 (6.9)
	Non-Queensland resident	34 (5.4)	27 (4.3)	61 (4.9)
SEIFA IRSD[c]	Most disadvantaged quintile	66 (10.5)	68 (10.9)	134 (10.7)
	2nd quintile	70 (11.1)	72 (11.5)	142 (11.3)
	3rd quintile	116 (18.4)	100 (16.0)	216 (17.2)
	4th quintile	134 (21.3)	150 (24.0)	284 (22.6)
	Least disadvantaged quintile	210 (33.3)	206 (33.0)	416 (33.2)
	Non-Queensland resident	34 (5.4)	27 (4.3)	61 (4.9)
Smoking status	Non-smoker	316 (50.2)	360 (57.7)	676 (53.9)
	Current / recent smoker	34 (5.4)	21 (3.4)	55 (4.4)
	Missing	280 (44.4)	243 (38.9)	523 (41.7)
Elixhauser comorbidity index	0	283 (44.9)	343 (55)	626 (49.9)
	1	56 (8.9)	59 (9.5)	115 (9.2)
	2+	27 (4.3)	28 (4.5)	55 (4.4)
	No hospital record prior to infection	264 (41.9)	194 (31.1)	458 (36.5)
Comorbid conditions[d]	Asthma	6 (1.0)	7 (1.1)	13 (1.0)
	Chronic lower respiratory disease	5 (0.8)	8 (1.3)	13 (1.0)
	Diabetes	30 (4.8)	23 (3.7)	53 (4.2)
	Renal failure	11 (1.7)	8 (1.3)	19 (1.5)
	Cancer	40 (6.3)	35 (5.6)	75 (6.0)
	Cardiovascular disease	60 (9.5)	37 (5.9)	97 (7.7)

a Sex, age, remoteness and SEIFA IRSD were sourced or derived from the NoCS data. Smoking status and comorbidities were obtained from QHAPDC data prior to onset date. SEIFA IRSD was measured in population-based quintiles. Smoking status was only recorded from 1 July 2015 and was not recorded for virtual ward home admissions.

b Accessibility and Remoteness Index of Australia.

c Socio-Economic Indexes for Areas, Index of Relative Socio-Economic Disadvantage.

d Asthma (ICD-10-AM: J45); chronic lower respiratory conditions excluding asthma (ICD-10-AM: J40-J47, excluding J45); diabetes (ICD-10-AM: E10-E14); renal failure (ICD-10-AM: N17-N19); cancer (ICD-10-AM: C00-C97); and major atherosclerotic/ thromboembolic cardiovascular disease (using established methods:[10] selected hypertensive diseases I11-I13; ischaemic heart disease I20-I25; pulmonary heart disease and diseases of pulmonary circulation I26-I28; other forms of heart disease I34-36, I42, I44, I46-I51; cerebrovascular disease I61-I67, I69; selected diseases of the arteries, arterioles and capillaries I70-I77; phlebitis and thrombophlebitis I80; and selected episodic and paroxysmal disorders G45, G46).

Ethics approval

Ethics approval was granted by the Gold Coast Hospital and Health Service Human Research Ethics Committee (HREC/2020/QGC/63555) and by the Australian National University Human Research Ethics Committee (2020/312). Informed consent was not required for this study and access to de-identified data was granted under Section 282 of the *Public Health Act 2005* by the Director-General's delegate.

Results

There were 1,254 people with a diagnosis of COVID-19 to 31 December 2020. Of these, 753 (60.0%) were linked to EDC data and most (n = 1,178; 93.4%) had a link to a QHAPDC record (since January 2010; 30,017 records). Of the cohort, there were 288 inpatient hospital admissions among 267 (21.3%) patients, while 796 (63.5%) people had a QHAPDC record in the ten years prior to onset date (3,981 records). There were six deaths in the linked Death Registrations dataset, consistent with the number of deaths reported by Queensland Health.

Characteristics of all people diagnosed with COVID-19 in Queensland

Two thirds of people in the Queensland COVID-19 cohort were in the 20–39 and 40–59 year age groups (38.7% and 29.0% respectively). Half of those in the cohort (49.8%) were women (Table 1). The majority of people (77.6%) were from major cities and a disproportionate number of cases were from the least disadvantaged areas (10.7% of cases were from the most disadvantaged quintile, compared to 33.2% from the least disadvantaged). Smoking status was missing for a large proportion of the cohort (523/1,254; 41.7%). Of those for whom smoking status could be established, the majority were non-smokers (n = 676/731; 92.5%) and a small proportion were recorded as current/recent smokers (n = 55/731; 7.5%).

For chronic health conditions captured in prior public hospital admissions, < 2% of the cohort had a previous hospital admission with a diagnosis of asthma (1.0%), chronic lower respiratory disease (1.0%) or renal failure (1.5%). Among the cohort, 4.2% had recorded diabetes; 6.0% cancer; and 7.7% major cardiovascular disease (CVD). The largest fraction of the cohort (n= 626/1,254; 49.9%) had none of the 30 comorbidities measured with the Elixhauser comorbidity index; 115 (9.2%) reported one comorbid condition; 55 (4.4%) reported two or more conditions; and 458 (36.5%) did not have a hospital record in the ten years prior to infection.

Outcomes for people diagnosed with COVID-19 in Queensland

There were 1,182 people in the cohort that had an onset date before 1 November 2020 (Table 2). The median number of days between symptom onset date and first hospitalisation was 4 (IQR: 2–7 days) and once admitted, median length of stay was 11 days (IQR: 8–16). A greater proportion of the cohort aged ≥ 60 years had an inpatient hospital admission compared to those < 60 years of age (29.9% compared to 18.1%). Seventeen members of the cohort (1.4%) with onset before 1 November 2020 were admitted to ICU, 14 (1.2%) required ventilation and 6 (0.5%) died. Small numbers experiencing these outcomes precluded any further analyses.

The NoCS data recorded that 337 patients (29%) were hospitalised, 752 (64%) were not hospitalised and hospitalisation status was not recorded for 93 cases (8%). By comparison, the QHAPDC stated that 250 (21%) patients required inpatient hospital admission, an additional 714 (60%) were home-based admissions, and 218 (18%) had no hospital record (Appendix A, Table A.1). The NoCS data recorded that 16 patients were admitted to ICU, and that 12 required ventilation, which was lower than the numbers recorded in the QHAPDC data (Appendix A, Tables A.2 and A.3). A large proportion of NoCS data pertaining to patient hospitalisation, ventilation, admission to ICU and death was not recorded (Appendix A, Tables A.1 to A.4).

Over half of the cohort with onset date prior to 1 November 2020 (57.6%; 681/1,182) presented

Table 2: Health outcomes for confirmed COVID-19 cases in Queensland (with onset before 1 November 2020),[a] through the Notifiable Conditions Systems (NoCS) data

		Male[b]	Female[b]	Total
Total	Presented to emergency department, n (%)	329 (56.0)	352 (59.2)	681 (57.6)
	• Inpatient hospital admission, n (%)	135 (23.0)	115 (19.3)	250 (21.2)
	• Length of stay (days), median (IQR)	12 (8–17)	11 (7–15)	11 (8–16)
	◦ Days between onset and hospitalisation, median (IQR)	4 (2–7)	5 (3–8)	4 (2–7)
	• Admitted to ICU, n (%)	n/a	n/a	17 (1.4)
	◦ Days between onset and ICU, median (IQR)	n/a	n/a	8 (6–10)
	• Required ventilation, n (%)	n/a	n/a	14 (1.2)
	• Days ventilated, median (IQR)	n/a	n/a	21 (11–35)
	• Died, n (%)	n/a	n/a	6 (0.5)
	◦ Days between onset and death, median (IQR)	n/a	n/a	11 (10–24)
Aged 0–59 years	Presented to emergency department, n (%)	220 (53.4)	258 (58.2)	478 (55.9)
	Inpatient hospital admission, n (%)	79 (19.2)	76 (17.2)	155 (18.1)
Aged 60+ years	Presented to emergency department, n (%)	109 (62.3)	94 (61.8)	203 (62.1)
	Inpatient hospital admission, n (%)	56 (32.0)	39 (25.7)	95 (29.1)

a Estimates are based on cohort members with an onset date prior to 1 November 2020 (n=1,182). Emergency department admissions are measured with EDC data; hospital admissions, ICU and continuous ventilator support are measured with the QHAPDC, deaths are ascertained with the Death Registrations data. Inpatient hospital records exclude home-based admissions. Hospital data is yet to be finalised and these results should be considered preliminary. At the time of writing, data relating to length of stay in ICU was not available. Length of stay has been estimated excluding the 13 (7.1%) patients admitted and discharged on the same day.

b n/a indicates that the result has been suppressed because of cell size < 5.

to an ED in the six-week follow-up period. The majority (n = 619/681; 90.9%) presented within two weeks of their symptom onset date. Proportions presenting did not vary substantially by broad age group (55.9% of those aged 0–59 years, compared to 62.1% of those aged 60+ years). Among those presenting to an ED, the most common primary diagnoses were COVID-19 (ICD-10: U07.1) and diagnoses related to viral and respiratory infections (Table 3). The ten most common diagnoses accounted for 89.2% of all principal diagnoses among those presenting to ED. Diagnoses were materially unchanged when restricted to presentations occurring within two weeks of the recorded symptom onset date (see Appendix A, Table A.5).

A total of 250/1,182 people (21.2%) in the COVID-19 cohort with onset before 1 November 2020 were admitted to hospital as an inpatient; the majority of admissions (n = 236/250; 94.4%) occurred within two weeks of recorded symptom onset date. Among those admitted to hospital, the most common diagnoses were COVID-19, coronavirus, isolation, and symptoms associated with COVID-19, including cough, fever and headache (Table 4). However, the top ten most common diagnoses accounted for less than half of all diagnoses (47.9%) among this patient cohort. Diagnoses were not materially different when restricted to admissions occurring within two weeks of recorded symptom onset date (Appendix A, Table A.6).

Table 3: Top 10 principal diagnosis codes among COVID-19 patients presenting to an emergency department in Queensland[a]

Rank	ICD-10-AM code	Definition of ICD-10-AM code	n	%	Cumulative %
1	U07.1	Emergency use of U07.1 (COVID-19)	288	28.8	28.8
2	B34.9	Viral infection, unspecified	271	27.1	55.9
3	Z11.5	Special screening examination for other viral diseases	225	22.5	78.4
4	J06.9	Acute upper respiratory infection, unspecified	36	3.6	82.0
5	B34.2	Coronavirus infection, unspecified site	29	2.9	84.9
6	Z09.9	Follow-up examination after unspecified treatment for other conditions	12	1.2	86.1
7	R07.4	Chest pain, unspecified	8	0.8	86.9
8	J22	Unspecified acute lower respiratory infection	8	0.8	87.7
9	J11.1	Influenza with other respiratory manifestations, virus not identified	8	0.8	88.5
10	R50.9	Fever, unspecified	7	0.7	89.2

a Estimates are based on 998 admissions among 681 patients. Outcomes are measured with EDC data.

Factors associated with a presentation to an emergency department or admission to hospital

There were 1,148 people who were residents of Queensland with an onset date before 1 November 2020. Among these people, there was little variation in risks associated with presentation to an ED in relation to sociodemographic characteristics after adjustment for age and sex (Table 5), other than that those residing in outer regional areas had lower risk of presenting to an ED than did those in major cities (age-sex-adjusted RR: 0.64; 95% CI: 0.44, 0.92; test for trend: $p = 0.007$). In age-sex-adjusted models, there was evidence that those in less-disadvantaged areas had higher risks of presenting to an ED (test for trend, $p = 0.014$); however, this association was no longer evident after ARIA+ region classification was considered.

Proportions admitted to hospital increased with age (< 20% of those aged 0–39 years to > 34% of those aged 75+ years); with being a current/recent smoker (42.2%) compared to being a non-smoker (27.9%); and with having a comorbid chronic health condition (26.3–38.5%) compared to having no comorbid condition (18.8%). There was considerable uncertainty in the estimates in the age-sex-adjusted models. However, risk of hospital admission increased with greater age (test for linear trend: $p < 0.001$) and was elevated among current/recent smokers compared to non-smokers (age-sex-adjusted RR:1.62; 95% CI: 1.00, 2.61); those living in less-disadvantaged areas had lower risk of being admitted to hospital (age-sex-adjusted test for trend, $p = 0.001$) (Model 1, Table 6). There was no material difference in these results after adjustment for region (Model 2, Table 6).

Sensitivity analyses

When comorbidities were measured using hopsitalisation records both before and after COVID-19 symptom onset, the proportions of cases with each of the comorbid health conditions increased slightly (see Appendix A, Table A.7). Associations between comorbid health conditions and presentation to emergency (Appendix A, Table A.8) were substantially unchanged. Associations between comorbid health conditions and inpatient hospital admissions did not change materially, except that those with renal failure had higher risk of hospital admission compared to those without (age-sex adjusted RR= 1.75; 95% CI: 1.07, 2.86; Appendix A, Table A.9).

Table 4: Top 10 principal diagnosis codes among COVID-19 patients requiring inpatient admission to hospital in Queensland[a]

Rank	ICD-10-AM code	Definition of ICD-10-AM code	n	%	Cumulative %
1	U07.1	Emergency use of U07.1 (COVID-19)	257	11.5	11.5
2	Z29.0	Isolation	234	10.5	22.0
3	B97.2	Coronavirus as the cause of disease classified to other chapters	216	9.7	31.7
4	R05	Cough	85	3.8	35.5
5	U82.3[b]	Hypertension	51	2.3	37.8
6	R50.9	Fever, unspecified	50	2.2	40.0
7	Z86.43	Personal history of psychoactive substance abuse, tobacco use disorder	49	2.2	42.2
8	B34.2	Coronavirus infection, unspecified site	45	2.0	44.2
9	J128	Other viral pneumonia	41	1.8	46.1
10	R51	Headache	40	1.8	47.9

a Estimates are based on 380 inpatient admissions among 250 patients. Outcomes are measured with data from the QHAPDC.

b U82.3 Hypertension is a supplementary code, assigned when a condition is present on admission but that does not meet the criteria for coding as instructed by the general and specialty coding standards, coding conventions, and coding rules.

Some caution should be applied when interpreting these results, as health conditions measured at the time or after onset may be the outcome of COVID-19 rather than a pre-existing condition. Similarly, associations between comorbid conditions and outcomes were materially unchanged when assuming those without a hospital record prior to onset date had none of the measured comorbidities (Appendix A, Tables A.10 and A.11).

Discussion

By linking administrative data, we described the characteristics, hospital-based outcomes and deaths for all confirmed COVID-19 cases in Queensland, and the utility of using linked data for ongoing surveillance purposes as the pandemic continues. Over half of people diagnosed had at least one ED presentation; one in five had an inpatient hospital admission (median length of stay 11 days), 1.4% were admitted to ICU (majority requiring ventilation) and six died. Increasing age and being a smoker were associated with higher risk of admission, while those in less-disadvantaged areas had lower risk of admission. There was some evidence that people with chronic health conditions had an elevated risk of being admitted; however, small numbers limited the precision of our estimates.

Our finding that presentations to an ED were relatively common is consistent with Queensland policies regarding testing location during the pandemic. The majority of those diagnosed with COVID-19 in Queensland acquired the virus overseas and were likely in quarantine when symptoms became apparent.[11] Emergency Departments were the first point of contact for these people. Even those not in quarantine were discouraged from entering GP clinics if they reported any COVID-19 related symptoms, and were instead referred to their nearest ED. This policy remained in place even after State and Commonwealth Governments established fever clinics which would have reduced the number of patients presenting to an ED. The only characteristic we examined that was associated with lower risk of presenting to an ED was living in an outer regional area, likely reflecting reduced access to an ED.

Table 5: Proportions and relative risks for emergency department presentation within two weeks of recorded symptom onset among Queensland residents with confirmed COVID-19,[a] in relation to key socio-demographic characteristics

		Events/ persons (%)	Model 1 RR (95% CI)	Model 2 RR (95% CI)
Total		**607/1,148 (52.9)**		
Age group (years)[b]	0–19	24/63 (38.1)	0.73 (0.48, 1.11)	0.72 (0.47, 1.09)
	20–39	226/432 (52.3)	1.00	1.00
	40–59	172/328 (52.4)	1.00 (0.82, 1.22)	1.01 (0.82, 1.23)
	60–74	148/264 (56.1)	1.07 (0.87, 1.32)	1.08 (0.88, 1.33)
	75+	37/61 (60.7)	1.16 (0.82, 1.65)	1.18 (0.83, 1.68)
Sex[b]	Male	300/566 (53.0)	1.00	1.00
	Female	307/582 (52.7)	1.00 (0.85, 1.18)	1.00 (0.85, 1.17)
ARIA+[c]	Major cities	516/935 (55.2)	1.00	–
	Inner regional	60/127 (47.2)	0.83 (0.64, 1.09)	–
	Outer regional / remote / very remote	30/85 (35.3)	0.64 (0.44, 0.92)[d]	–
SEIFA IRSD[e]	Most disadvantaged quintile	56/127 (44.1)	1.00	1.00
	2nd quintile	62/141 (44)	0.97 (0.67, 1.39)	1.03 (0.71, 1.48)
	3rd quintile	105/199 (52.8)	1.19 (0.86, 1.65)	1.19 (0.85, 1.67)
	4th quintile	152/277 (54.9)	1.25 (0.92, 1.69)	1.20 (0.86, 1.66)
	Least disadvantaged quintile	231/403 (57.3)	1.32 (0.98, 1.77)[f]	1.25 (0.92, 1.71)
Smoking status	Non-smoker	357/613 (58.2)	1.00	1.00
	Current / recent smoker	26/45 (57.8)	1.00 (0.67, 1.50)	1.00 (0.67, 1.49)
	Missing	224/490 (45.7)	0.80 (0.68, 0.95)	0.78 (0.66, 0.93)
Elixhauser comorbidity index	0	326/612 (53.3)	1.00	1.00
	1	64/113 (56.6)	1.03 (0.78, 1.36)	1.04 (0.79, 1.36)
	2+	28/54 (51.9)	0.93 (0.63, 1.38)	0.95 (0.64, 1.41)
	No hospital record prior to infection	189/369 (51.2)	0.99 (0.82, 1.19)	0.98 (0.82, 1.18)
Comorbid conditions[g]	Asthma	8/12 (66.7)	1.28 (0.64, 2.59)	1.24 (0.61, 2.51)
	Chronic lower respiratory disease	9/13 (69.2)	1.22 (0.63, 2.40)	1.21 (0.61, 2.36)
	Diabetes	34/52 (65.4)	1.18 (0.82, 1.70)	1.22 (0.84, 1.76)
	Renal failure	11/19 (57.9)	1.03 (0.56, 1.89)	1.03 (0.56, 1.89)
	Cancer	37/73 (50.7)	0.88 (0.62, 1.25)	0.88 (0.62, 1.25)
	Cardiovascular disease	54/97 (55.7)	0.98 (0.73, 1.33)	1.00 (0.74, 1.36)

a Estimates are based on 1,148 people who were residents of Queensland with an onset date before 1 November 2020 and 607 presentations to emergency departments, measured with EDC data. Model 1 is adjusted for age and sex. Model 2 is adjusted for age, sex and remoteness, measured with ARIA+. Age, sex, remoteness and SEIFA IRSD are measured with or derived from NoCS data. Smoking status and comorbidities are measured with QHAPDC prior to onset date. SEIFA IRSD is measured in population-based quintiles.

b Where age is the primary exposure variable, Model 1 is adjusted only for sex. Where sex is the primary exposure variable, Model 1 is adjusted for only age. EDC data is yet to be finalised and results should be considered preliminary.

c Accessibility and Remoteness Index of Australia.

d Indicates that the test for linear trend was significant, $p < 0.01$.

e Socio-Economic Indexes for Areas, Index of Relative Socio-Economic Disadvantage.

f Indicates that the test for linear trend was significant, $p < 0.05$.

g Risks associated with comorbid conditions are estimated for each condition separately, using those with a hospital record but without the condition as the reference category.

Table 6: Proportions and relative risks for an inpatient admission to hospital within two weeks of recorded COVID-19 symptom onset,[a] among Queensland residents in relation to key sociodemographic characteristics

		Events/ persons (%)	Model 1 RR (95% CI)	Model 2 RR (95% CI)
Total		**227/1148 (19.8)**		
Age group (years)[b]	0–19	11/ 63 (17.5)	1.13 (0.60, 2.14)	1.18 (0.62, 2.23)
	20–39	66/ 432 (15.3)	1.00	1.00
	40–59	61/ 328 (18.6)	1.19 (0.84, 1.69)	1.19 (0.84, 1.69)
	60–74	68/ 264 (25.8)	1.66 (1.19, 2.34)	1.68 (1.19, 2.36)
	75+	21/ 61 (34.4)	2.17 (1.32, 3.56)[c]	2.20 (1.34, 3.63)[c]
Sex[b]	Male	124/566 (21.9)	1.00	1.00
	Female	103/582 (17.7)	0.85 (0.65, 1.10)	0.86 (0.66, 1.11)
ARIA+[d]	Major cities	171/935 (18.3)	1.00	–
	Inner regional	28/127 (22)	1.08 (0.72, 1.62)	–
	Outer regional / remote / very remote	28/85 (32.9)	1.83 (1.22, 2.73)[e]	–
SEIFA IRSD[f]	Most disadvantaged quintile	45/127 (35.4)	1.00	1.00
	2nd quintile	38/141 (27)	0.74 (0.48, 1.15)	0.70 (0.45, 1.08)
	3rd quintile	46/199 (23.1)	0.67 (0.45, 1.02)	0.60 (0.39, 0.92)
	4th quintile	56/277 (20.2)	0.60 (0.40, 0.89)	0.55 (0.36, 0.83)
	Least disadvantaged quintile	42/403 (10.4)	0.32 (0.21, 0.48)[c]	0.30 (0.19, 0.46)[c]
Smoking status	Non-smoker	171/613 (27.9)	1.00	1.00
	Current / recent smoker	19/45 (42.2)	1.62 (1.00, 2.61)	1.61 (1.00, 2.61)
	Missing	37/490 (7.6)	0.27 (0.19, 0.39)	0.28 (0.19, 0.40)
Elixhauser comorbidity index	0	115/612 (18.8)	1.00	1.00
	1	30/113 (26.5)	1.22 (0.81, 1.84)	1.21 (0.80, 1.82)
	2+	15/54 (27.8)	1.21 (0.70, 2.10)	1.20 (0.69, 2.08)
	No hospital record prior to infection	67/369 (18.2)	1.03 (0.76, 1.41)	1.03 (0.76, 1.41)
Comorbid conditions[g]	Asthma	< 5/12 (< 42.0)	1.15 (0.37, 3.63)	1.22 (0.39, 3.84)
	Chronic lower respiratory disease	5/13 (38.5)	1.47 (0.59, 3.66)	1.54 (0.62, 3.85)
	Diabetes	16/52 (30.8)	1.18 (0.69, 2.01)	1.23 (0.66, 1.94)
	Renal failure	5/19 (26.3)	1.00 (0.41, 2.46)	1.04 (0.42, 2.57)
	Cancer	20/73 (27.4)	1.07 (0.66, 1.75)	1.08 (0.66, 1.77)
	Cardiovascular disease	28/97 (28.9)	1.13 (0.74, 1.75)	1.12 (0.73, 1.73)

a Estimates are based on 1,148 people who were residents of Queensland with an onset date before 1 November 2020 and 227 inpatient hospital admissions, measured with QHAPDC data. Model 1 is adjusted for age and sex. Model 2 is adjusted for age, sex and remoteness, measured with ARIA+. Age, sex, remoteness and SEIFA IRSD are measured with or derived from NoCS data. Smoking status and comorbidities are measured with hospital data prior to onset date. SEIFA IRSD is measured in population-based quintiles.

b Where age is the primary exposure variable, Model 1 is adjusted only for sex. Where sex is the primary exposure variable, Model 1 is adjusted for only age. QHAPDC data is yet to be finalised and results should be considered preliminary.

c Indicates that the test for linear trend was significant, $p < 0.001$.

d Accessibility and Remoteness Index of Australia.

e Indicates that the test for linear trend was significant, $p < 0.01$.

f Socio-Economic Indexes for Areas, Index of Relative Socio-Economic Disadvantage.

g Risks associated with comorbid conditions are estimated for each condition separately, using those with a hospital record but without the condition as the reference category.

Proportions of people diagnosed with COVID-19 experiencing adverse outcomes are likely to be dependent on a number of region-specific factors, including population profile, health system factors and the public health actions taken by individuals and Government. Furthermore, international comparisons with people diagnosed with COVID-19 in Queensland are difficult, given that most previous research examines outcomes among ED presentations and hospitalised COVID-19 patients and/or expresses outcomes as rates (rather than proportions).[12,13]

The associations between person characteristics and inpatient hospital admissions in the Queensland COVID-19 cohort were consistent with what is already known about adverse outcomes in people diagnosed with COVID-19. Previous research has found that increasing age, being a smoker and area-level deprivation are associated with adverse outcomes in people diagnosed with COVID-19 compared to other members of the population, as are chronic health conditions such as respiratory disease (excluding asthma), cardiovascular disease, diabetes, recent cancer and reduced kidney function.[14,15]

This project demonstrates the value of data linkage across health services to monitor outcomes and contribute to the international evidence on COVID-19. NoCS data, whilst valuable, is limited by incomplete data records, by the impracticability of collecting extra information such as comorbidities, and by the time needed for long-term follow-up. Queensland Health already has a wide array of established data sets which contain valuable and additional health care information. Linking NoCS data to additional data sources – hopsitalisations, emergency department and death data – has enabled additional and complementary data for people with COVID-19 (including more complete outcome data), ultimately increasing the value of the NoCS data collected from case report forms. Furthermore, it has allowed for ascertainment of hospital-based and death outcomes for all people diagnosed with COVID-19, which has been limited in many international settings to only those admitted to hospital. Having established the resource, the ATHENA COVID-19 Study can now also be used a platform for monitoring longer-term outcomes. In order to both strengthen and increase the utility of existing notifiable disease surveillance systems against future pandemics, it would seem prudent to routinely establish the linkage capabilities between these different databases.

Nonetheless, our findings, particularly those regarding associations between pre-existing conditions and hospital outcomes, should be interpreted with data limitations in mind. Hospital data were limited to Queensland public hospitals. There were no Queensland COVID-19-related admissions to private hospitals in Queensland or to hospitals outside the state, and hence, ascertainment of hospital outcomes is likely complete. However, our measure of comorbidities based on hospital data (in the ten years prior to COVID-19 diagnosis) is likely incomplete, given some cohort members may have been admitted to private hospital or to a hospital outside Queensland in the relevant period. There may also be missing data due to linkage error. Consequently, prevalence of these conditions will be underestimated, which may or may not have affected RR estimates of the associations between chronic conditions and inpatient hospital admission. The sociodemographic and health characteristics included were limited to the data that were available; other information, including more detail on health conditions and information on medications, would have been useful. Discrepancies between the NoCS and QHAPDC data most likely reflect a combination of non-recorded data (NoCS) and no hospital record available (QHAPDC). That 93%, rather than 100%, of COVID-19 patients had data linked to QHAPDC is likely due to the delay in virtual wards being set up. During this period, those patients who were asymptomatic or mildly ill would not have required admission to hospital and therefore would not have evidence of admitted data. Finally, reflecting the success that Queensland showed in curbing the pandemic, there were small numbers of COVID-19 cases in this study. This resulted in considerable uncertainty in estimates of association between

characteristics and outcomes, limiting our ability to examine factors predicting hospital-based outcomes.

The ATHENA COVID-19 Study is now an established resource. While Australia's success managing the pandemic has ensured cases have remained low since the peak of the pandemic in Queensland in late March 2020, the ATHENA COVID-19 Study can be used for monitoring of COVID-19 outcomes should there be another wave or increased community transmission, as well as longer-term follow-up. Furthermore, the data could be aggregated with similar data from other Australian states and territories to increase their analytical power.

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Appendix A: Supplementary tables

Table A.1: Number of cases with onset date before 1 November 2020 reported as being hospitalised in the Notifiable Conditions System data (NoCS) and the linked data from Queensland Health Admitted Patient Data Collection (QHAPDC)

		QHAPDC data			
		No hospital record	Home-based admission	Inpatient hospital admission	Total
NoCS data	Not hospitalised	194	500	58	752
	Hospitalised	14	146	177	337
	Not recorded	10	68	15	93
	Total	**218**	**714**	**250**	**1,182**

Table A.2: Number of cases with onset date before 1 November 2020 reported as requiring ventilation in the NoCS data and the linked data from QHAPDC

		QHAPDC data			
		No hospital record	Not ventilated	Required ventilation	Total[a]
NoCS data	Not ventilated	40	217	< 5	XXXX
	Required ventilation	< 5	< 5	< 5	12
	Not recorded	177	733	< 5	XXXX
	Total[a]	**XXXX**	**XXXX**	**14**	**1,182**

a 'XXXX' indicates that the number has been suppressed.

Table A.3: Number of cases with onset date before 1 November 2020 reported as being admitted to an Intensive Care Unit (ICU) in the NoCS data and the linked data from QHAPDC

		QHAPDC data			
		No hospital record	Not admitted to ICU[a]	Admitted to ICU	Total[a]
NoCS data	Not admitted to ICU	156	649	< 5	XXXX
	Admitted to ICU	< 5	XXXX	< 5	16
	Not recorded	59	298	< 5	XXXX
	Total[a]	**XXXX**	**XXXX**	**17**	**1,182**

a 'XXXX' indicates that the number has been suppressed.

Table A.4: Number of cases with onset date before 1 November 2020 reported as having died in the NoCS data and the linked Death Registrations data

		Death Registrations data		
		No record	Died	Total[a]
NoCS data	Not recorded as having died	959	< 5	XXXX
	Recorded as having died	< 5	< 5	6
	Not recorded	XXXX	< 5	XXXX
	Total[a]	**1,176**	**6**	**1,182**

a 'XXXX' indicates that the number has been suppressed.

Table A.5: Top 10 principal diagnosis codes among COVID-19 patients presenting to an emergency department in Queensland within two weeks of recorded symptom onset date[a]

Rank	ICD-10-AM code	Definition of ICD-10-AM code	n	%	Cumulative %
1	B34.9	Viral infection, unspecified	236	31.9	31.9
2	U07.1	Emergency use of U07.1 (COVID-19)	191	25.8	57.7
3	Z11.5	Special screening examination for other viral diseases	167	22.6	80.3
4	J06.9	Acute upper respiratory infection, unspecified	31	4.2	84.5
5	B34.2	Coronavirus infection, unspecified site	28	3.8	88.2
6	J18.9	Pneumonia, unspecified	7	0.9	89.2
7	J11.1	Influenza with other respiratory manifestations, virus not identified	7	0.9	90.1
8	R50.9	Fever, unspecified	7	0.9	91.1
9	R07.4	Chest pain, unspecified	5	0.7	91.8
10	J22	Unspecified acute lower respiratory infection	5	0.7	92.4

a Estimates are based on 740 presentations among 622 patients. Outcomes are measured with data from the QHAPDC.

Table A.6: Top 10 principal diagnosis codes among COVID-19 patients within two weeks of recorded symptom onset date requiring inpatient admission to hospital in Queensland[a]

Rank	ICD-10-AM code	Definition of ICD-10-AM code	n	%	Cumulative %
1	U07.1	Emergency use of U07.1 (COVID-19)	240	11.7	11.7
2	Z29.0	Isolation	219	10.7	22.4
3	B97.2	Coronavirus	200	9.7	32.1
4	R05	Cough	77	3.8	35.8
5	U82.3[b]	Hypertension	45	2.2	38.0
6	R50.9	Fever	45	2.2	40.2
7	B34.2	Coronavirus infection unspecific site	43	2.1	42.3
8	Z86.43	Personal history of psychoactive substance abuse, tobacco use disorder	43	2.1	44.4
9	J128	Other viral pneumonia	40	1.9	46.4
10	R51	Headache	35	1.7	48.1

a Estimates are based on 1065 inpatient admissions among 938 patients. Outcomes are measured with data from the QHAPDC.

b U82.3 Hypertension is a supplementary code, assigned when a condition is present on admission but that does not meet the criteria for coding as instructed by the general and specialty coding standards, coding conventions, and coding rules.

Table A.7: Proportions of confirmed COVID-19 cases with comorbid chronic health conditions,[a] measured using all available QHAPDC records

Comorbidity	Male n (%)	Female n (%)	Total n (%)
Asthma	16 (2.5)	22 (3.5)	38 (3.0)
Chronic lower respiratory disease	10 (1.6)	9 (1.4)	19 (1.5)
Diabetes	43 (6.8)	30 (4.8)	73 (5.8)
Renal failure	28 (4.4)	12 (1.9)	40 (3.2)
Cancer	40 (6.3)	35 (5.6)	75 (6.0)
Cardiovascular Disease (CVD)	73 (11.6)	40 (6.4)	113 (9.0)

a Estimates are based on all 1,254 cohort members.

Table A.8: Crude and age-sex-adjusted risks for emergency department presentation among Queensland residents with confirmed COVID-19 in relation to comorbid conditions,[a] including QHAPDC records post COVID-19 onset

Comorbidity	Events/persons (%)	Age-sex-adjusted RR (95% CI)
Asthma	26/36 (72.2)	1.13 (0.76, 1.68)
Chronic lower respiratory disease	15/18 (83.3)	1.25 (0.73, 2.14)
Diabetes	45/68 (66.2)	1.00 (0.72, 1.37)
Renal failure	27/39 (69.2)	1.05 (0.70, 1.56)
Cancer	44/73 (60.3)	0.88 (0.63, 1.22)
Cardiovascular Disease (CVD)	72/112 (64.3)	0.97 (0.74, 1.28)

a Estimates are based on 1,148 cohort members who were Queensland residents and had an onset date before 1 November 2020.

Table A.9: Crude and age-sex-adjusted risks for inpatient hospital admission within 2 weeks of symptoms onset among Queensland residents with confirmed COVID-19 in relation to comorbid conditions,[a] including QHPADC records post COVID-19 onset

Comorbidity	Events/persons (%)	Age-sex-adjusted RR (95% CI)
Asthma	11/36 (30.6)	1.32 (0.71, 2.45)
Chronic lower respiratory disease	9/18 (50.0)	1.65 (0.81, 3.36)
Diabetes	22/68 (32.4)	1.10 (0.69, 1.76)
Renal failure	20/39 (51.3)	1.75 (1.07, 2.86)
Cancer	20/73 (27.4)	0.91 (0.56, 1.48)
Cardiovascular Disease (CVD)	40/112 (35.7)	1.30 (0.88, 1.92)

a Estimates are based on 1,148 cohort members who were Queensland residents and had an onset date before 1 November 2020.

Table A.10: Crude and age-sex-adjusted risks for emergency department presentation among Queensland residents with confirmed COVID-19 in relation to comorbid conditions,[a] assuming patients with no QHAPDC records prior to onset had none of the measured comorbidities

Comorbidity	Events/persons (%)	Age-sex-adjusted RR (95% CI)
Asthma	9/12 (75.0)	1.31 (0.68, 2.53)
Chronic lower respiratory disease	11/13 (84.6)	1.36 (0.74, 2.50)
Diabetes	37/52 (71.2)	1.17 (0.83, 1.67)
Renal failure	12/19 (63.2)	1.03 (0.58, 1.84)
Cancer	44/73 (60.3)	0.97 (0.71, 1.34)
Cardiovascular Disease (CVD)	59/97 (60.8)	0.99 (0.75, 1.32)

a Estimates are based on 1,148 cohort members who were Queensland residents and had an onset date before 1 November 2020.

Table A.11: Crude and age-sex-adjusted risks for inpatient hospital admission within two weeks of symptoms onset among Queensland residents with confirmed COVID-19 in relation to comorbid conditions,[a] assuming patients with no QHAPDC records prior to onset had none of the measured comorbidities

Comorbidity	Events/persons (%)	Age-sex-adjusted RR (95% CI)
Asthma	< 5/12 (<42)	1.15 (0.37, 3.63)
Chronic lower respiratory disease	5/13 (38.5)	1.48 (0.60, 3.66)
Diabetes	16/52 (30.8)	1.18 (0.69, 2.01)
Renal failure	5/19 (26.3)	1.00 (0.41, 2.46)
Cancer	20/73 (27.4)	1.07 (0.66, 1.74)
Cardiovascular Disease (CVD)	28/97 (28.9)	1.13 (0.74, 1.74)

a Estimates are based on 1,148 cohort members who were Queensland residents and had an onset date before 1 November 2020.